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A PECULIAR FORMATION OF SHORE ICE

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On January 27 of the current year the writer noticed that the ice along the Milwaukee shore of Lake Michigan from Lake Park to the city pumping-station, a distance of nearly a mile, was formed almost entirely of large snowballs such as are formed by children rolling the damp snow until it grows into a ball by accretion. The phenomenon was so peculiar that it led to a more careful study, and as the author has found no report of a similar condition, it seems worth while reporting.

The beach where the peculiar formation occurred is not wide, varying from only 3 or 4 feet to as much as 50 or 60; on the landward side it terminates at the bottom of an 80-foot bluff of glacial material, composed of the unstratified boulder clay at the bottom and stratified sands and clays above, culminating in the "red lake clay" characteristic of the Wisconsin shore of Lake Michigan. Beyond the edge of the beach the water is very shallow for a considerable distance out, so that in time of even moderate waves boulders of 3 and 4 feet in diameter appear in the trough of the waves 100 and more feet from shore. This bench has been formed by the waves cutting into the cliff and distributing the material on the adjacent bottom. During ordinary winters this shallow water freezes to the bottom very early, so that the ice-foot is far out beyond the usual water-line. The exceptionally mild winter of 1905-6 did not permit the water to freeze far out, so that at the end of January there was only a very narrow zone of shore ice, extending out not over 50-100 feet.

At the time of the author's visit the condition was somewhat as follows: There had been several very mild days with decided thawing, and the beach presented the appearance of a compact mass of balls of semi-solid ice, which upon investigation turned out to be masses of snow crystals which, by thawing and freezing

and by additions from the water of the lake, had grown to the diameter of a millimeter or two. The mass of ice had been broken along several parallel lines and displaced, showing a thickness of 3-4 feet; and this showed that the beach ice was a mass of the snowballs cemented by snow and frozen spray. The beach at this point runs slightly west of south, and the snowballs on the surface had



FIG. 1.—A group of large snowballs showing concentric arrangement of layers of dirt and snow.

been forced into prominence by the melting away of the softer cementing snow between them; moreover, about one-third of each ball was melted away on the south side. The southern faces which had suffered by melting presented a most peculiar appearance, which led to the recognition of the true nature of the balls. As shown in the figures, the melting had caused the contained dirt to accumulate on the surface, and it appeared as concentric rings. Close examination showed that this dirt was true beach sand and gravel. All the balls, varying in size from 3 inches to 3 or 4 feet, showed the same concentric arrangement, but in some the layers were alternately snow and clearer ice rather than snow and sand.

There seems but one explanation of this very queer phenomenon: the balls were rolled by the waves. The beach is a flat, smooth sand beach, and the water is very shallow for a considerable distance out. It seems that in some snowstorm early in the winter, before any ice-foot had formed, the beach must have been covered with 2 or 3 inches of a snow (the layers of the snowballs are from an inch to an inch and a half in their present compacted condition),



FIG. 2—A large snowball about 3 feet in diameter, half melted and showing concentric structure.

in a very damp and soggy state, perhaps filling the water adjacent to the shore with a heavy slush. The water must have been very close to the freezing-point, so that there was little or no melting of the snow as it came in contact with the water. Now, a rise of the wind would produce a surge which, moving up the beach and back, started the snow in motion, and as the snow was water-soaked, and too heavy to float with any buoyancy, it was pushed back and forth until it was compressed into a small mass which began to roll. There is no distinct nucleus to the balls either of harder snow or of small pieces of ice, as might be expected, but the center

seems the same as the outer parts. As the balls grew in size, it is evident that they rolled on the solid beach, gathering up a layer equal to the thickness of the snow on the beach, and including a thin layer of the sand and small gravel in the bottom of the layer.

The scarcity of the phenomenon seems amply accounted for by the peculiar conditions necessary for its production. There must be wide, flat beach such that the surge of the waves can carry them forward and back for a considerable distance; the water must be reduced to the freezing-point without the formation of an ice-foot which would hold the waves off the beach; and there must be a mass of soft, damp snow ready for the action of the waves.